Collider-Accelerator Department

Building 911-A
P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344-5272
Fax 631 344-5676
rck@bnl.gov

BROOKHAVEN NATIONAL LABORATORY

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

Date: November 28, 2003

To: W. Gunther

From: R. Karol

Subject: Medical Department Animal MRI ODH Calculations

Purpose

As requested by the LESHC, I have completed calculations to determine the proper Oxygen Deficiency Hazard (ODH) Classifications of the Building 490 Animal MRI Room using the guidance from the BNL SBMS Subject Area, Oxygen Deficiency Hazards, System Classifications and Controls.

Conclusions

The following operating states were examined to determine the appropriate ODH classifications:

Normal Operations – small venting of nitrogen and helium occurs into the MRI room, which is well ventilated and monitored for oxygen content. Routine room entries occur (many per hour) to conduct experiments.
Quenching Event – releases large amounts of helium from the magnet via an emergency discharge pipe that is vented directly to the roof of Building 490. Quenches can be initiated automatically to protect the super-conducting magnet or manually to protect personnel.
Powered Cryogenic Magnet-can Failure – this assumes that the magnet-can ruptures, releasing helium or nitrogen into the MRI room.
Routine Top-off Operations – about every week for LN_2 and every month for LHe.
Initial filling operations – this is already completed for the installed magnet but may occur periodically following magnet system repairs.

The calculations documented in the next section show the ODH classifications for each operating mode. The results are summarized in Table 1, Animal MRI ODH Classification Summary.

It is recommended that the facility be posted ODH 0 when it contains LHe and/or LN_2 and ODH 1 when performing initial filling or routine top-offs.

Details of Calculations

A walkthrough of the MRI area was conducted on November 24, 2003 with E. Lessard, R. Colichio and C. Harris. The room has a free volume of ~2835 ft^3 (2890 ft^3 room minus 54 ft^3 magnet). The exhaust flow rate is 1000 CFM (fan EF2), with all intake fresh air. Volumes other than the MRI room are conservatively ignored, including the opening above the magnet used for rigging the magnet into and out of the room.

1. Normal Operations

The attached figure shows the normal venting flow rates of nitrogen and helium (Venting Arrangement 9.4T210AS, P&I Diagram dated 30-July-2003). Converting routine boil-off to gas volume rates at 300 K room temperature, results in 0.06 CFM helium gas and 0.24 CFM nitrogen gas inputs into the room, which is a total of 0.3 CFM of inert gas. This is obviously so small that the room's oxygen concentration will never fall below 21% with EF2 operating. In fact it would take over 6 days for the room to fall to 19.5% oxygen if the fan were off and it was assumed that no fresh air were to enter the room. Thus for normal operations, no ODH classification is required.

2. Quenching Event

Quenching events can occur to protect the magnet or can be manually initiated to quickly reduce the magnet field for personnel protection. A quench can be also be initiated by placing a warm bayonet into the system during top-off operations, which is considered separately in Section 3. The released helium gas passes through a burst disk, a flexible connection held in place with hose clamps and a stainless steel pipe that vents the gas directly to outside the room to the roof. A quench event is safe with respect to ODH unless the quench discharge line pressure boundary fails, allowing helium to enter the MRI room.

The attached figure shows the quench venting flow rate for helium (Venting Arrangement 9.4T210AS, P&I Diagram dated 30-July-2003). The figure shows that 2894 kg/hr of helium are released during a quench event. Converting this to helium gas at 300K results in an enormous spill rate of 10,464 CFM. This far exceeds the exhaust fan flow rate of 1000 CFM. The total volume of LHe in the magnet is 1050 L (37.1 ft^3). Using the expansion factor of LHe (4.2K) to GHe (300K room temperature) of 768 results in a total volume of 28,493 ft^3 GHe. Thus the room's oxygen concentration would rapidly fall to 0% if the quench vent pipe failed.

The remainder of this calculation thus needs to determine the probability of a quench simultaneously with a quench vent line pressure boundary failure. A quench is judged to occur once every five years (2×10^{-5}/hr). The vent line is 6" diameter stainless steel pipe in four-sections that is connected to the magnet burst disk by a flexible line held on with hose clamps. The failure of the stainless steel line is 4×10^{-10}/hr (four sections of pipe > 3" diameter). The flex line and hose clamps failure rate is determined by using engineering judgment because no value for this configuration is given in the BNL ODH Subject Area. A similar arrangement was used at the HFBR for fuel discharging operations to allow air-cooling of spent fuel elements. This arrangement was used at two locations for over 30 years without failure. There were about 300 refueling operations at the HFBR with the two flex-line vents attached for about 8 hours per discharging operation. Thus a very conservative failure rate would be 2×10^{-4}/hr. Given the fact that a magnet quench would cause a rapid pressurization of the vent pipe, the failure rate of the flexible portion of the vent pipe is increased by a factor of twenty to a rate of 4×10^{-3}/demand. Thus the flex line failure dominates the quench line pressure boundary failure rate.

The probability of a quench (2×10^{-5}/hr) simultaneously with a flex line failure (4×10^{-3} per demand) is 8×10^{-8}/hr. Note that any personnel actions to escape the room when the quench event began were conservatively ignored in this estimate.

Thus a quench event results in a required MRI room posting of ODH 0 because the fatality factor (1) times the frequency of the event (8×10^{-8}/hr) results in a fatality rate that is $<10^{-7}$/hr.

3. Powered Cryogenic Magnet-Can Failure

This simple scenario assumes that the magnet-can pressure boundary fails, releasing a large volume of LHe in a short interval. The SBMS value for pressure boundary failures of powered cryogenic magnets is

2×10^{-7}/hr. This failure rate applies to a pressurized magnet such as those at RHIC (~4 to 15 atm). Because the MRI magnet has a much lower pressure, the failure rate was reduced by a factor of four, using engineering judgment, to a value of 5×10^{-8}/hr.

Thus a magnet-can failure results in a required MRI room posting of ODH 0 because the fatality factor (1) times the frequency of the event (5×10^{-8}/hr) results in a fatality rate that is $<10^{-7}$/hr.

4. Routine Top-Off Operations

Routine top-off operations occur by using dewars to top-off the LHe and LN_2 in the magnet can. Two things can cause a helium or nitrogen release: 1) adding a warm bayonet to the system causing release of helium or nitrogen into the room, 2) a quench can occur if to much heat is added by the bayonet.

The SBMS value of 1×10^{-3} per demand is used for a large event caused by improper bayonet operations.

If the quench event were to follow this excessive heating by the bayonet, the probability of a release of helium into the room via a failed quench exhaust line would be (1×10^{-3} per demand)(4×10^{-3}/demand[1]) or 4×10^{-6}/demand. The rate of helium release would be so high that the fatality factor would be 1. Conservatively ignoring any emergency actions by the person in the room (i.e., removal of the bayonet or escape from the room), the fatality factor would be equal to 4×10^{-6}/demand. This value is between 10^{-5} and 10^{-7}, thus an ODH classification of 1 is needed during routine filling operations.

Improper bayonet usage that causes excessive boil-off of LHe or LN_2, short of causing a magnet quench, is bounded by the above scenario.

5. Initial Fill Operations

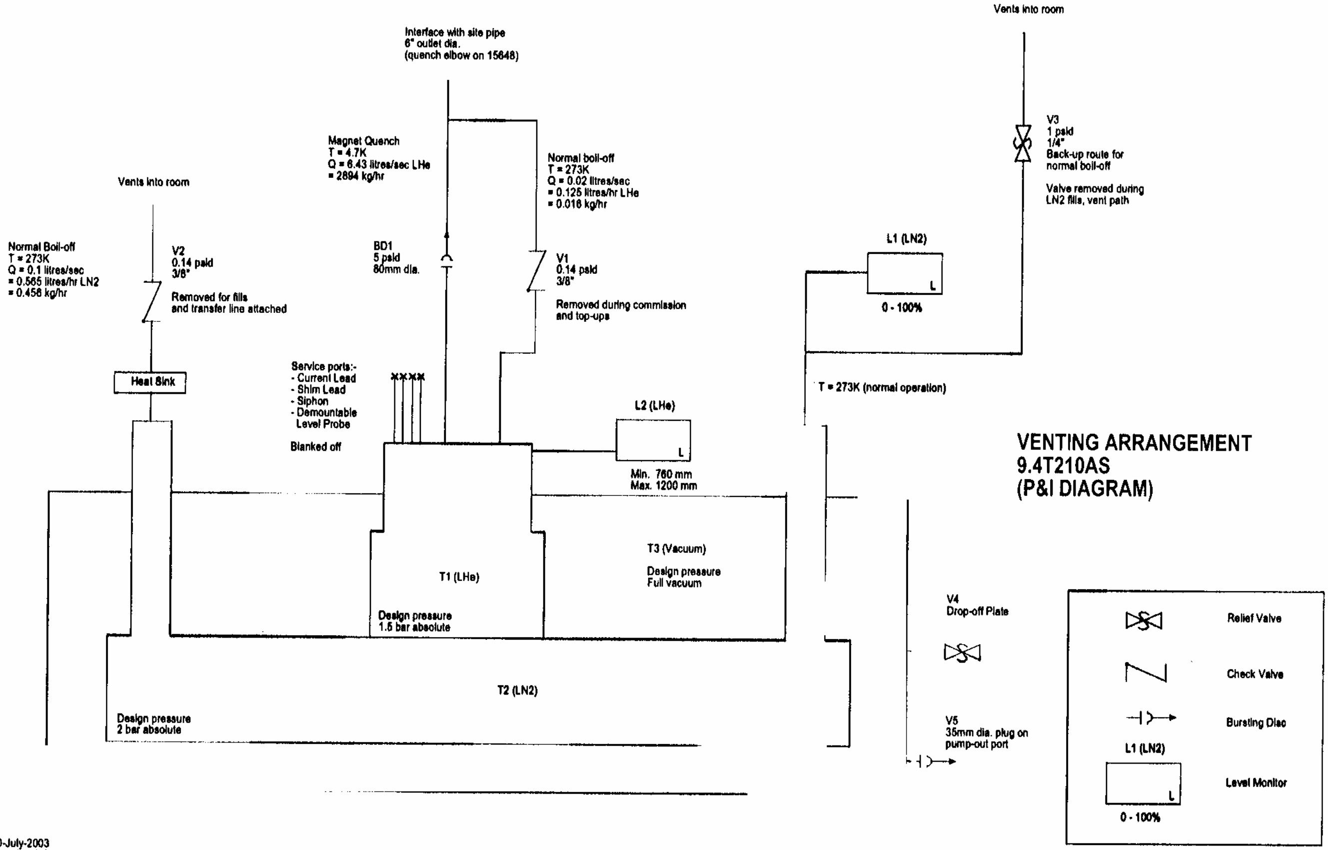
Initial fill operations have already taken place. Based upon review of the procedures and discussion with personnel who operate the facility, initial fill operations are no different than routine top-off operations (Section 4) with the exception that it takes a longer time to complete initial filling. In addition, initial filling cannot cause a magnet quench since the magnet is not energized. Thus, posting the area as ODH 1 during filling is judged to be conservative and provides more than adequate safety of operating personnel.

Cc: E. Lessard C. Du
R. Coilichio

[1] See Section 2, Quenching Event.

Table 1
Animal MRI ODH Classification Summary

Operating Mode	**Maximum Spill Rate (SCFM)**	**Frequency**	**Fatality Factor**	**Fatality Rate**	**ODH Classification**
Normal Operations	0.3	1	0	0	NA
Magnet Quenching Events	10,464 CFM	8×10^{-8}/hr	1	8×10^{-8}/hr	0
Powered Magnet Can Rupture	Very High	5×10^{-8}/hr	1	5×10^{-8}/hr	0
Routine Top-Off Operations	10,464 CFM	4×10^{-6}	1	4×10^{-6}	1
Initial Fill Operations	Low to High	$< 4 \times 10^{-6}$	1	$< 4 \times 10^{-6}$	1



VENTING ARRANGEMENT
9.4T210AS
(P&I DIAGRAM)

30-July-2003
Autosketch file "pid_std"